Sitting Time and Waist Circumference Are Associated With Glycemia in UK South Asians

Sitting Time and Waist Circumference Are Associated With Glycemia in U.K. South Asians

Data from 1,228 adults screened for the PODOSA trial

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OBJECTIVE—To investigate the independent contributions of waist circumference, physical activity, and sedentary behavior on glycemia in South Asians living in Scotland.

RESEARCH DESIGN AND METHODS—Participants were 1,228 (523 men and 705 women) adults of Indian or Pakistani origin screened for the Prevention of Type 2 Diabetes and Obesity in South Asians (PODOSA) trial. All undertook an oral glucose tolerance test, had physical activity and sitting time assessed by International Physical Activity Questionnaire, and had waist circumference measured.

RESULTS—Mean ± SD age and waist circumference were 49.8 ± 10.1 years and 99.2 ± 10.2 cm, respectively. One hundred ninety-one participants had impaired fasting glycemia or impaired glucose tolerance, and 97 had possible type 2 diabetes. In multivariate regression analysis, age (0.012 mmol · L^{-1} · $year^{-1}$ [95% CI 0.006–0.017]) and waist circumference (0.018 mmol · L^{-1} · cm^{-1} [0.012–0.024]) were significantly independently associated with fasting glucose concentration, and age (0.032 mmol · L^{-1} · $year^{-1}$ [0.016–0.049]), waist (0.057 mmol · L^{-1} · cm^{-1} [0.040–0.074]), and sitting time (0.097 mmol · L^{-1} · h^{-1} · day^{-1} [0.036–0.158]) were significantly independently associated with 2-h glucose concentration. Vigorous activity time had a borderline significant association with 2-h glucose concentration (−0.819 mmol · L^{-1} · h^{-1} · day^{-1} [−1.672 to 0.034]) in the multivariate model.

CONCLUSIONS—These data highlight an important relationship between sitting time and 2-h glucose levels in U.K. South Asians, independent of physical activity and waist circumference. Although the data are cross-sectional and thus do not permit firm conclusions about causality to be drawn, the results suggest that further study investigating the effects of sitting time on glycemia and other aspects of metabolic risk in South Asian populations is warranted.

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South Asians living in the U.K. have a three- to fivefold increased age-standardized prevalence of type 2 diabetes and develop the disease approximately a decade earlier compared with the background white European–origin population (1,2). Approximately one-quarter of U.K. South Asians over the age of 55 years have type 2 diabetes, and a similar proportion exhibit impaired glucose tolerance (IGT) (1–3). Obesity, generally assessed by BMI or waist circumference, has been shown to be a strong risk factor for type 2 diabetes (4) and impaired glucose regulation (5), and the increased diabetes/IGT risk observed in South Asians is likely to be due in part to the fact that, for a given BMI, South Asians possess greater amounts of total and abdominal fat (6,7). However, increased adiposity alone does not fully explain South Asians' excess diabetes risk (8). Low levels of physical activity are also associated with increased risk of diabetes (9), and studies of physical activity in U.K. adults consistently report lower physical activity in South Asians than in White Europeans (10,11); thus, low activity could conceivably contribute to the increased prevalence of glucose dysregulation in this population. However, because physical activity levels influence adiposity and adjustment for adiposity attenuates the protective effect of physical activity (9), it is unclear whether low physical activity contributes to the increased risk of diabetes and IGT in U.K. South Asians independently of adiposity. In addition, there is a growing body of evidence that indicates that sedentary time (i.e., time spent sitting down) is associated with increased risk of type 2 diabetes and directly influences a number of vascular and metabolic risk factors independent of time spent in physical activity (12). The effects of sedentary behavior on glycemia in South Asians have not previously been investigated.

Therefore, the purpose of this study was to investigate the independent contributions of waist circumference (as an index of abdominal obesity), physical activity, and sedentary behavior on indices of glycemia in South Asians living in Scotland.

RESEARCH DESIGN AND METHODS

—Participants in this analysis all volunteered to be screened for participation in the Prevention of Type 2 Diabetes and Obesity in South Asians (PODOSA) trial, which is a cluster randomized controlled trial investigating whether family-based lifestyle intervention (dietary modification and increased physical activity) can induce long-term weight loss and prevent diabetes in individuals

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with IGT and/or impaired fasting glycemia (IFG) of Indian and Pakistani origin living in the NHS Greater Glasgow and Clyde and NHS Lothian health board areas. Inclusion criteria for screening in the PODOSA trial were as follows: age ≥35 years, waist circumference ≥90 cm for men and ≥80 cm for women, and no confirmed medical history of diabetes. The PODOSA trial is registered with the International Standard Randomized Controlled Trial Number Register (ISRCTN25729565), and further details of the trial are available on the ISRCTN website (http://www.controlled-trials.com/isrctn/). Volunteers for screening were recruited using a multipronged approach including written invitations via general practitioners (family doctors) and direct referrals from health care professionals. The majority were recruited by word of mouth, referrals from local South Asian community groups, and by direct approaches by the research team. The study was approved by the Scotland A Research ethics committee, and all volunteers gave written informed consent.

Participants all underwent a standard 75-g oral glucose tolerance test in their own homes, with venous blood samples taken after an overnight fast of 10–16 h and 2 h after ingestion of 75 g glucose. Blood was collected into tubes containing sodium fluoride and then transported to a central hospital laboratory (Glasgow Royal Infirmary [GRI] or Western General Hospital [WGH], Edinburgh) where plasma was separated, usually within 4 h of collection, and plasma glucose concentration was determined using the Ortho clinical diagnostics, Fusion dry ice method (at WGH), or the Abbott Architect, hexokinase/glucose-6-phosphate dehydrogenase method (at GRI). Both laboratories participate in the U.K. National External Quality Assessment Service (UK NEQAS) scheme. Waist circumference was measured by trained dietitians at the midpoint between iliac crest and lower costal border over bare skin or a single layer of light clothing following a standard operating procedure (SOP). Two measurements of waist circumference were made. If these differed by ≤1.0 cm, the mean value was used; if these two measurements differed by >1.0 cm, a third measurement was made and the two closest values were used to calculate the mean. All dietitians participated in regular quality control sessions to ensure that the SOP was followed and to check variability within and between dietitians. Physical activity was assessed using the short form of the International Physical Activity Questionnaire (IPAQ), which asks questions on amount of walking (in bouts of at least 10 min) undertaken and participation in moderate and vigorous activities over the past 7 days and on the time spent sitting on weekdays over the same period (13). The IPAQ was phonetically translated into Hindi, Urdu, and Punjabi by a panel comprising multilingual members of the PODOSA study team and four lay community members fluent in these languages. A translated version of the IPAQ (rather than English) was used when the participant felt more comfortable communicating in that language.

Data analysis

Data were analyzed using Minitab (version 14). Time spent sitting, walking, and undertaking moderate and vigorous activities were extracted from the IPAQ, with time spent walking and in moderate and vigorous activities truncated at 180 min per day in line with the published IPAQ data processing guidelines (www.ipaq.ki.se). Time spent sitting, walking, in vigorous activity, in moderate activity, in moderate-to-vigorous activity (moderate plus vigorous activity time [MVPA]), and in total activity (walking plus MVPA) and waist circumference were used as continuous variables in data analysis. Univariate regression analyses (adjusted for the potential confounding effects of age and sex) were performed to determine the associations of waist circumference, sitting time, and time spent in different activity domains on fasting and 2-h glucose concentrations. Multivariate linear regression analyses were undertaken to determine the independent associations of age, sex, waist circumference, sitting time, and time spent in different activity domains (walking, moderate, and vigorous activity) on fasting and 2-h glucose concentrations. To ensure that overall findings were not distorted by the inclusion of participants with possible diabetes, analyses were repeated excluding these individuals. Data are presented as mean (95% CI) unless otherwise stated, and statistical significance was accepted at $P < 0.05$.

RESULTS—Characteristics of the study population are shown in Table 1. According to 1999 World Health Organization (WHO) criteria (14), 76.5% of the study population was normoglycemic (fasting plasma glucose ≤6.0 mmol/L and 2-h post–glucose load plasma glucose <7.8 mmol/L), 15.6% had impaired fasting glucose (IFG) (fasting glucose 6.1–6.9 mmol/L) and/or IGT (2-h glucose 7.8–11.0 mmol/L), and 7.9% had possible undiagnosed diabetes (fasting glucose ≥7.0 mmol/L and/or 2-h glucose ≥11.1 mmol/L).

Correlates of fasting and 2-h glucose concentrations

Age was a significant correlate of both fasting (0.014 mmol/L increase per year [95% CI 0.008–0.020]) and 2-h (0.044 mmol/L increase per year [0.027–0.060]) glucose concentrations. Men had higher fasting (0.217 mmol/L [0.101–0.333]) and 2-h (0.424 mmol/L [0.077–0.771]) concentrations than women. Thus, all further analyses were adjusted for age and sex.

Age- and sex-adjusted univariate correlates of fasting and 2-h glucose concentrations are shown in Table 2. Waist circumference was a significant correlate of fasting glucose concentration ($P < 0.0005$), but there was no significant association between sitting time or any index of activity and fasting glucose concentration. Increasing waist circumference

Table 1—*Characteristics of the study population*

N (men/women)	523/705
Age (years)	49.8 ± 10.1 (35–89)
Location (Glasgow/Edinburgh)	802/426
Ethnicity (Indian/Pakistani)	421/807
Fasting glucose concentration (mmol/L)	5.32 ± 1.02 (2.9–15.6)
Two-hour glucose concentration (mmol/L)	6.41 ± 3.07 (1.9–30.7)
Glycemic status (normoglycemic/IFG–IGT/diabetes)	940/191/97
Waist circumference (cm)	99.2 ± 10.2 (80–139)
Sitting time (h/day)	5.75 ± 2.90 (0.0–17.3)
Walking time (h/day)	0.39 ± 0.66 (0.0–3.0)
Vigorous activity time (h/day)	0.04 ± 0.20 (0.0–3.0)
Moderate-to-vigorous activity time (h/day)	0.27 ± 0.63 (0.0–3.0)
Total activity time (h/day)	0.66 ± 1.06 (0.0–9.0)

Data are *n* or means ± SD (range).

Table 2—*Age- and sex-adjusted univariate correlates of fasting and 2-h glucose concentration in individuals screened for the PODOSA trial* (n = 1,228)

	Fasting glucose concentration		Two-hour glucose concentration	
	Difference in glucose (mmol/L)	*P*	Difference in glucose (mmol/L)	*P*
Waist (per cm)	0.019 (0.013–0.025)	<0.0005	0.060 (0.042–0.078)	<0.0005
Sitting time (per h/day)	0.016 (−0.004 to 0.036)	0.128	0.129 (0.068–0.190)	<0.0005
Total activity time (per h/day)	0.010 (−0.043 to 0.063)	0.717	−0.212 (−0.373 to −0.051)	0.010
Walking time (per h/day)	0.006 (−0.080 to 0.092)	0.890	−0.223 (−0.482 to 0.036)	0.090
Moderate activity time (per h/day)	0.043 (−0.059 to 0.144)	0.414	−0.302 (−0.607 to 0.004)	0.054
Vigorous activity time (per h/day)	−0.117 (−0.401 to 0.167)	0.419	−1.087 (−1.944 to −0.230)	0.013
MVPA time (per h/day)	0.022 (−0.068 to 0.112)	0.639	−0.359 (−0.631 to −0.087)	0.010

Data are means (95% CI).

and sitting time were associated with increasing 2-h glucose concentration, and increasing time in vigorous, MVPA, and total activity was associated with decreasing 2-h glucose concentrations.

Correlates of fasting and 2-h glucose concentrations in multivariate analysis are shown in Table 3. Variables included in the model were as follows: age, sex, waist circumference, sitting time, walking time, moderate activity time, and vigorous activity time. Age and waist circumference were significantly independently associated with fasting glucose concentration; and age, waist, and sitting time were significantly independently associated with 2-h glucose concentration. The univariate association of vigorous activity time with 2-h glucose concentration was attenuated to borderline significance ($P = 0.06$) in the multivariate model. When the analysis was repeated replacing the moderate and vigorous activity categories in the model with MVPA or replacing walking, moderate, and vigorous activity with total activity, the results were unchanged, with age, waist, and sitting time remaining significantly independently associated with 2-h glucose concentration and the associations of none of the activity variables with 2-h glucose achieving statistical significance. Repeating the analysis excluding participants with possible diabetes yielded similar results.

CONCLUSIONS—The main finding of this study was that time spent sitting down and waist circumference were associated with 2-h post–glucose load plasma glucose concentrations in South Asians living in the U.K. independently of age, sex, and self-reported physical activity patterns. Times spent in vigorous, MVPA, and total activity were significant correlates of 2-h glucose concentrations in (age- and sex-adjusted) univariate analysis, but other than vigorous activity retaining borderline significance, these associations were lost in the multivariate model.

The relationship between increased waist circumference and fasting and 2-h glucose concentration is expected and has been demonstrated on numerous occasions in a wide range of populations (4), although, to the authors' knowledge, this has not previously been reported in a study of this scale in Indian- and Pakistani-origin populations in the U.K. However, the major novel finding of this study is that sitting time was a significant correlate of 2-h glucose concentration independent of waist circumference, indicating that in this population the effects of sitting on glycemia went beyond its potential role in modulating central adiposity. One of the most striking observations is that the association of sitting time with 2-h glucose concentration was independent of indices of physical activity (albeit derived from questionnaire) in multivariate regression, highlighting the potential importance of sedentary time as an independent behavior category and not just an absence of physical activity when considering the effects of lifestyle variables on metabolic risk. An adverse effect of increasing sedentary time (principally assessed by self-reported television viewing time) on glycemia and/or risk of type 2 diabetes has been demonstrated in Australian (15,16), U.S. (17,18), and U.K. adults (19), although not all studies report this association (20) and the association has not always been independent of time spent in physical activity (19). The present data extend these observations to U.K. South Asians, and although these data are cross-sectional and thus do not permit

Table 3—*Correlates of fasting and 2-h glucose concentration in multivariate regression analysis in individuals screened for the PODOSA trial* (n = 1,228)

	Fasting glucose concentration		Two-hour glucose concentration	
	Difference in glucose (mmol/L)	*P*	Difference in glucose (mmol/L)	*P*
Age (per year)	0.012 (0.006–0.017)	<0.0005	0.032 (0.016–0.049)	<0.0005
Sex (men compared with women)	−0.082 (−0.203 to 0.040)	0.183	0.000 (−0.360 to 0.360)	0.999
Waist (per cm)	0.018 (0.012–0.024)	<0.0005	0.057 (0.040–0.074)	<0.0005
Sitting time (per h/day)	0.012 (−0.009 to 0.033)	0.251	0.097 (0.036–0.158)	0.002
Walking time (per h/day)	0.013 (−0.079 to 0.104)	0.784	−0.040 (−0.312 to 0.232)	0.774
Moderate activity time (per h/day)	0.070 (−0.040 to 0.180)	0.212	−0.083 (−0.410 to 0.244)	0.620
Vigorous activity time (per h/day)	−0.100 (−0.386 to 0.186)	0.492	−0.819 (−1.672 to 0.034)	0.060

Data are means (95% CI).

conclusions about causality to be drawn, they do make a case for further study into the potential role of reducing sedentary behavior (i.e., spending less time sitting down) on glycemia and/or risk of type 2 diabetes in South Asian populations. The need for intervention studies to assess the effects of reducing sedentary behavior on health outcomes has recently been highlighted (12).

In a recent report, Yates et al. (11) only found a borderline significant effect of physical activity level on 2-h glucose concentrations in South Asian men living in Leicester, U.K., and found no association in women. This contrasts somewhat with the present observations, in which total, vigorous activity, and MVPA were significant correlates of 2-h glucose in univariate analysis. There are two major possible explanations for this discrepancy. Firstly, the population in the current study was recruited because they had large waists and thus had higher waist circumferences (99.2 vs. 91.6 cm) than those in the study of Yates et al. They were also likely to be more insulin resistant, with higher 2-h glucose concentrations (6.4 vs. 5.6 mmol/L). The importance of physical activity for glucose regulation is likely to be greater (or more readily detected) in more obese populations that are more insulin resistant and have poorer glucose control (9). Secondly, in contrast to the study of Yates et al., we considered physical activity as a continuous rather than categorical variable and considered the effects of different activity domains separately. This approach may have revealed relationships that were masked by simply classifying individuals as having low, moderate, or high levels of physical activity. In particular, we found a stronger inverse relationship between time spent in vigorous activity and 2-h glucose concentration than that observed for moderate activity. This is consistent with evidence that vigorous activity may have greater effects on insulin resistance than equivalent amounts of moderate-intensity activity (21,22). However, because the number of individuals reporting any vigorous activity was small (n = 133, 10.8% of the cohort) and mean time spent in vigorous activity was just 2.4 min per day, this finding should be taken with a degree of caution.

Each additional hour spent sitting per day was associated with a 0.1 mmol/L increase in 2-h glucose concentration in the multivariate model, an effect size equivalent to a 2-cm difference in waist circumference or a 3-year difference in age. Though this effect size is relatively modest, it may be of clinical relevance. Reported sitting time varied widely within this cohort—ranging from 0 to 17 h per day—and a 1 mmol/L difference in 2-h glucose was associated with a 6% increase in all-cause and an 8% increase in cardiovascular mortality risk, independent of other major risk factors, in a report from a large American cohort (23).

It is of interest to note that physical activity and sitting time were associated with 2-h, but not fasting, glucose concentrations. This may reflect the different metabolic determinants of fasting and 2-h glucose concentrations, with basal insulin secretion and hepatic insulin sensitivity being the key determinants of the former and peripheral insulin sensitivity having a much greater influence on the latter (24). Thus, the finding that physical activity and sitting time associated only with 2-h glucose in the present cohort may reflect a greater influence of these factors on peripheral insulin sensitivity than on basal insulin secretion and hepatic insulin sensitivity. In contrast, waist circumference associated with both fasting and 2-h glucose concentrations, which may reflect an influence of adiposity on the metabolic determinants of both glycemic indices.

This study is not without its limitations. The most important of these relates to our measures of physical activity and sitting time. In common with the majority of large-scale studies, we assessed these factors by self-reported questionnaire. The IPAQ has been well validated in a range of settings and contexts and has been shown to perform at least as well as other established self-report physical activity measures (13). However, there are clear limitations to questionnaires, particularly in their ability to quantify activities at the lower end of the intensity spectrum (25). Nevertheless, it should be emphasized that any inaccuracies in the measurement of physical activity and sitting time in the current study would act to diminish the apparent effect of these behaviors on glycemia and waist circumference (a regression dilution bias effect) and, thus, the actual effects of physical activity and sitting time on these outcomes is likely to be at least as strong as demonstrated in the present report. Clearly, however, future studies are needed with objective measures of both activity and sedentary time in South Asian populations to verify the present findings. In addition, we did not record volunteers' height and body mass at screening and thus have used waist circumference rather than BMI as a measure of adiposity. However, because waist circumference has been shown to be equally predictive of incident diabetes as BMI in meta-analysis (4), this is unlikely to have had a major adverse effect on the validity of our findings. Finally, as this study was cross-sectional with the exposure and outcome measures were made at the same time, it not possible to definitively exclude reverse causality as a potential influence on the findings (i.e., high glucose concentrations leading to increased sitting time or reduced activity). However, it seems unlikely that this would have had a major influence on the results for two reasons. Firstly, the influence of sitting time on 2-h glucose concentration persisted after excluding participants with possible diabetes (i.e., excluding those with high and potentially symptomatic glucose concentrations), and secondly, prospective data in other population groups have shown that both television viewing time (17,18) and physical activity level (9) are significant predictors of incident diabetes.

In conclusion, the present findings of this study show that waist circumference and time spent sitting were associated with 2-h glucose concentrations in U.K. South Asian adults independently of age, sex, and self-reported physical activity levels. Though conclusions cannot be drawn about causality, the strength of the relationship between time spent sitting with glycemia, the wide range of sitting time within the population, and the fact that sitting is potentially a modifiable behavior suggest that further study is warranted to investigate the effects of reducing sitting time on glycemia and other aspects of metabolic risk in populations of South Asian origin.

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